GEOLOGIC RECONNAISSANCE OF THE YUKON FLATS CENOZOIC BASIN, ALASKA

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CONTENTS

ILLUSTRATIONS

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INTRODUCTION

The proposed dam in the Rampart Canyon of the Yukon River would create a reservoir of approximately 10,700 square miles. About 90 percent of the reservoir would lie in the Yukon Flats Cenozoic Basin and 5 percent in embayments extending up valleys tributary to the Yukon Flats. The remainder of the reservoir would occupy the 105-mile long Fort Hamlin-Rampart section of the Yukon Valley and the lower valleys of Hess Creek, Ray River, and lesser streams (fig. 1). It would extend up the Yukon Valley almost as far as Woodchopper and up the Porcupine River to Old Rampart House. When filled, the reservoir would have a volume of 1,300,000,000 acre-feet and a surface elevation of about 660 feet above sea level (Gronewald, 1960). If the entire average annual flow of the Yukon at Rampart, 80,650,000 acre-feet (U. S. Geological Survey, 1963), were impounded by the dam, the reservoir would require almost 16 years to fill. It would cover the villages of Rampart, Stevens, Beaver, Fort Yukon, Circle, Venetie, and Chalkytsik, which, together with smaller settlements, have a population of approximately 1,500 (U. S. Department of Commerce, 1960).

64-164

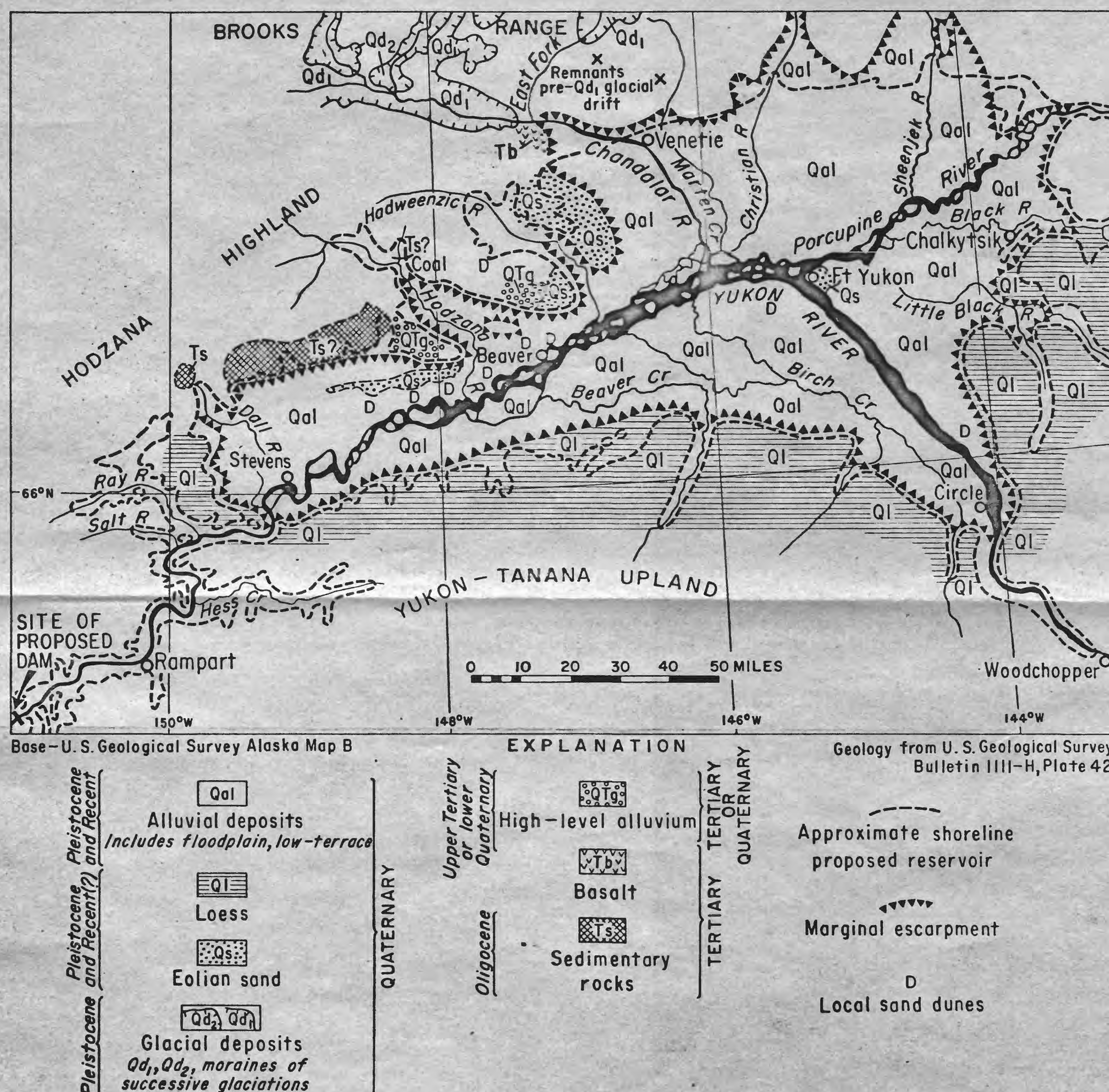

FIGURE I.—GENERALIZED GEOLOGY, YUKON FLATS CENOZOIC BASIN

The Yukon Flats Cenozoic Basin (fig:1) is divided into two major physiographic units: (a) the Yukon Flats, an alluvial lowland of about 9,000 square miles, most of which would be occupied by the reservoir, and (b) the marginal upland, a dissected to rolling bench that slopes from the surrounding highlands to the Yukon Flats. Separating the upland from the Yukon Flats is a marginal escarpment that rises 100 to 700 feet above adjacent parts of the Flats. Similar bluffs border the narrow valleys of the major streams through the marginal upland. Small streams have cut a network of gullies in the upland near the escarpment. The bluffs would form a steep shoreline bordering most of the reservoir, and low-lying, gently shelving shorelines would be formed only on the alluvial fans bordering the Chandalar, Christian, and Sheenjek Rivers and where the larger streams enter the upper end of embayments up tributary valleys. In a few places the marginal upland would be inundated by the reservoir. Small islands would be formed at some of these places, but elsewhere the reservoir would have deep water near shore.

The geologic reconnaissance on which this report is based was made in 1948-1950; the results are described more fully in U.S. Geological Survey Bulletin 1111-H (Williams, 1962). Geologic investigations by the Survey since 1950 have been made, or are now in progress, in the Yukon-Tanana Upland near Livengood, in the Circle area, in the southern Brooks Range, and in the region bounded by the Yukon and Porcupine Rivers and the Alaska-Yukon boundary; geophysical work includes gravity and aeromagnetic surveys of the Yukon Flats. Other organizations have made studies in connection with the proposed dam and to evaluate the oil and gas potential of the Yukon Flats basin.

GEOLOGY

PRE-CENOZOIC BASEMENT ROCKS

Sedimentary, metamorphic, and associated volcanic and intrusive igneous rocks form the highlands that border the Yukon Flats Cenozoic Basin. These rocks extend into the marginal upland, where they lie beneath the Cenozoic rocks, and crop out locally in the marginal escarpment north of the Yukon River and in river bluffs in the marginal upland. Exposures of basement rocks are uncommon in the escarpment and upland south of the Yukon River. Pre-Cenozoic rocks are not exposed in the Yukon Flats and were not encountered in a test well drilled to an elevation of 20 feet above sea level at Fort Yukon[1]. The lowest known point in the rim of pre-Cenozoic rocks bordering the basin is at least 800 feet above sea level in the canyon walls bordering the Yukon River at the lower end of the Yukon Flats. Therefore, the Yukon Flats occupy a tectonic basin at least 800 feet deep in the upper surface of the pre-Cenozoic basement.

[1] Fort Yukon waterwell No. 2, drilled 1954 by Alaska District, Corps of Engineers, U. S. Army.

CENOZOIC ROCKS

Cenozoic rocks of the marginal upland consist of consolidated sedimentary rocks and volcanic rocks of Tertiary age, unconsolidated high-level alluvium of late Tertiary or early Quaternary age, and eolian sand, loess, and alluvium of Quaternary age.

In the Yukon Flats consolidated sedimentary rocks of Tertiary age have not been recognized in the Fort Yukon test well. The well apparently did not reach the base of the silt and silty sand of late Tertiary or early Quaternary age, which is overlain by alluvial deposits of Quaternary age. The alluvial deposits consist of alluvial-fan and related terrace deposits, flood-plain and low-terrace alluvium, and alluvial-fan silt deposits. The alluvial deposits are covered locally by eolian sand, and in isolated places by thin eolian silt.

TERTIARY ROCKS

Sedimentary Rocks

Along the Dall River and its tributary, Coal Creek, folded shale and lignitic coal are exposed. Near the forks of the Hodzana River (fig. 1), subbituminous coal is reportedly associated with mud. Between these localities are approximately 150 square miles of the marginal upland in which flat-lying stratified rocks are known only from the study of aerial photographs. These rocks may be of the same lithology and age as the coal-bearing rocks on Dall and Hodzana Rivers. The age of the sedimentary rocks on the Dall River was given as Eocene by Mendenhall (1902) on the basis of lithologic similarity to the Kenai Formation and equivalent rocks in Interior Alaska. However, recent paleontological studies of the Tertiary rocks (MacNeil and others, 1961) at the type locality and at Rampart have shown that their age is Oligocene.

Basalt

Basaltic lava flows, dikes, and sills of Tertiary age (8) are exposed in the marginal upland south of the confluence of the Chandalar River and East Fork.

TERTIARY OR QUATERNARY DEPOSITS

Silt and Silty Sand

Silt and silty sand are known only in the subsurface in the Yukon Flats at Fort Yukon, where they were encountered at a depth of 148 feet in the Corps of Engineers test well. The test hole, 440 feet deep, did not reach the base of these deposits, which lie beneath the alluvial deposits of Quaternary age. The silt and silty sand are interpreted as quiet-water (lacustrine?) deposits of late Tertiary or early Quaternary age. A sample of silty sand collected by G. S. Tulloch, Brooklyn College, Brooklyn, New York from 393 feet was examined for pollen by W. S. Benninghoff. Pollen of pine, spruce, alder, birch, hemlock, and fir is abundant. Pollen of two Asiatic genera of the hickory family, *Pterocarya* and *Platycarya* is present. MacNeil and others (1961) state that the pollen assemblage seems intermediate between floras from beds of late Miocene or early Pliocene age and those of late Pliocene or early Pleistocene age in the Aldan River valley of northeastern Siberia. Thus, both the stratigraphic position of the sediments and their pollen content indicate a late Tertiary or possibly early Quaternary age.

High-level Alluvium

Unconsolidated high-level alluvium lies on older consolidated rocks wherever observed in the marginal upland. However, the deposits are largely buried by younger eolian deposits. The alluvium consists of beds and lenses of gravel, sand, and silt. It is locally cemented and stained by iron oxide. Although the maximum observed thickness is about 100 feet, it probably is greater locally. The deposits were formed (a) as alluvial aprons deposited by small streams draining the adjoining highlands, and (b) by the Yukon and its larger tributaries. South of lower Beaver Creek, for example, the marginal upland is divided into a dissected, loess-covered, north-sloping alluvial apron fronting the Yukon-Tanana upland and a lower, dissected, loess-covered Yukon terrace that is only 150 to 250 feet above the adjacent part of the Yukon Flats. The break in slope between these surfaces is obscured by the loess mantle and by extensive gullying. The landforms are so well masked by the loess mantle, and field observations are so few, that it is not possible to describe in any detail the complex system of high-terrace deposits and ancient alluvial aprons that are probably included in the high-level alluvium. Lack of deformation of these deposits and their unconsolidated condition show that they postdate the Miocene(?) deformation of the Tertiary (Oligocene?) consolidated deposits. The alluvium of even the 150 to 250-ft. Yukon terrace and the higher alluvial deposits lie well above the level to which the older part (early to middle Pleistocene) of the Chandalar alluvial fan was graded. The high-level alluvium of the marginal upland, therefore, is older than early to middle

Pleistocene, and is of late Tertiary or early Quaternary age. Preliminary examination of wood and pollen from the alluvium exposed in bluffs near Birch Creek bridge on Steese Highway (D. M. Hopkins, written communication, 1960) shows the presence of spruce and pine wood and pollen of spruce, fir(?), birch, alder, and shrubs. The flora is somewhat similar to that obtained from the silt and silty sand in the Fort Yukon well. However, no evidence as to the relative age of the two groups of deposits of late Tertiary or early Quaternary age is yet available because they have not been observed in contact.

QUATERNARY DEPOSITS

Glacial Deposits

Deposits of four glaciations are recognized in the southern Brooks Range and in the foothills adjacent to the Yukon Flats Cenozoic Basin. Identification of the deposits is based on study of aerial photography and the literature, but not on field observations by the writer. The oldest glaciation is represented by scattered patches of drift and apparent ice-scoured summits above and beyond the oldest recognizable end and lateral moraines (fig. 1) in the valleys of Marten Creek, East Fork, and Chandalar River. The deposits along upper Marten Creek were also recognized by Brosgé and Reiser (1962). No recognizable moraine limits the drift sheet, but additional studies may show that the glacier extended into the northern Yukon Flats via the Chandalar and Marten Valleys, and perhaps the Sheenjek Valley.

The outer limits of three later glaciations are marked by end and lateral moraines. The oldest and next oldest moraines are shown on fig. 1; the youngest lies within the Brooks Range north of the map area. The scattered drift of the oldest glaciation is probably early Pleistocene, perhaps correlative with the Anaktuvuk River Glaciation of the Arctic Slope of the Brooks Range (Detterman, Bowsher, and Dutro, 1958). The oldest recognizable moraine is early to middle Pleistocene, perhaps equivalent to the Sagvanirktok River Glaciation (Detterman, Bowsher, and Dutro, 1958), and the youngest two moraines are middle to late Pleistocene, probably equivalent, respectively, to the Itkillik and Echooka River Glaciations, which are correlated with the Wisconsin Glaciation of the mid-continent area. Others (Karlstrom, 1957), however, regard the Itkillik as of Illinoian and Sangamon age, and the Echooka River Glaciation of Wisconsin age. Further work on the glacial sequence of the southern Brooks Range not only is of scientific importance, but may provide a chronology to which the eolian and alluvial deposits of the Yukon Flats can be correlated.

Eolian Sand and Loess

Eolian sand underlies at least 250 square miles of the marginal upland north of the Yukon River and 200 square miles of the Yukon Flats. Loess forms a blanket over almost all of the marginal upland west, south, and east of the Yukon Flats. The eolian sand is massive, well-sorted, unconsolidated gray to tan sand and silty sand which ranges in thickness from 6 to 60 feet. The loess is massive, well-sorted, unconsolidated gray to tan silt and sandy silt. The well-sorted character of the silt, its relatively uniform texture and size distribution over a large area, its lack of obvious stratification, its local association with sand dunes, and lack of well-defined upper limits suggest that the silt is of eolian origin. The loess has been retransported by running water and mixed with organic material in creek valleys and in the alluvial-silt fans at the edge of the Yukon Flats. The thickness of the loess is unknown, but may be as much as 50 feet where undisturbed, and perhaps as much as 100 feet in creek valleys and fans.

The position of the thick loess mantle on the marginal upland west, south, and east of the Yukon Flats, the presence of eolian sand on the upland to the north, and the form of the dunes suggest that the winds were dominantly from the north. The northerly winds, perhaps strengthened by the proximity of glaciers in the adjacent Brooks Range, apparently swept across the bars of the braided rivers on the alluvial fans and transported sediment to the marginal upland; forming dunes locally in the upland and in the Yukon Flats. At the present time, winds form dust clouds of only local extent and form dunes only along the larger river bars. Therefore, although a small amount of the eolian deposits may be of Recent age, most is regarded as of Pleistocene age.

Alluvial Deposits

Alluvial deposits consisting of gravel, sand and silt form the surficial deposits of the Yukon Flats, except where locally covered by dune sand. These deposits form the large alluvial fans bordering the major rivers, small alluvial fans deposited by creeks at the edge of the Yukon Flats near the base of the marginal escarpment, and a narrow band of flood-plain and low-terrace deposits bordering the rivers. The alluvial deposits are reported to be 100 feet thick in the Fort Yukon test well.

Alluvial fans of the major rivers and related river terraces occupy most of the eastern and central Yukon Flats. The fan of the Yukon River extends 65 miles along the river from Circle to Fort Yukon and is bounded on the north and south by marginal escarpment. The large alluvial fans of the Chandalar, Christian, and Sheenjek Rivers coalesce near their toes, and border the north bank of the Yukon and Porcupine Rivers from near Beaver to the point at which the Porcupine River enters the Flats--a distance of more than 100 miles.

Generally, the fans are divided into two broad units: (a) a younger part which borders and grades into the flood plain and low terraces along the axial rivers, and (b) an older part that is preserved as a complex of river terraces that are slightly higher than the younger fan complex;

locally, the older parts of some fans are buried by younger fan deposits. The younger parts of the fans are covered with fresher-appearing braided channel scrolls, and have a soil profile in which the exidized zone is generally less than 2 feet thick. The older parts have a less well preserved system of abandoned scrolls, and an oxidized zone that is deeper than 2 feet. The older parts of the fans lie north of the Yukon River, between the Yukon and Birch Creek and along the east side of the Sheenjek, Christian, and Chandalar Rivers. Terraces bordering the Porcupine and Black Rivers appear correlative with the older parts of the alluvial fans of the other rivers. The terraces in the western part of the Flats are either downstream continuations of the alluvial fans, or terraces that were formed by alternating aggradation and degradation of the tributaries, in response to lateral migration of the Yukon.

The alluvial fan deposits and related terrace deposits are of Quaternary age, chiefly Pleistocene, although some of the lower surfaces bordering the flood plain may be of Recent age. The best method for dating the alluvial sequence would be to trace the terraces represented in the older parts of the alluvial fans upstream to the glacial moraines in the Brooks Range, especially along Marten Creek and the Chandalar River. The oldest lateral moraine of the East Fork Glacier forms the divide between the East Fork and Marten Creek. From this moraine an outwash plain leads to a valley-train terrace bordering upper Marten Creek. The valley train continues into an alluvial fan deposited by Marten Creek at the edge of the Flats. The fan appears to have been graded to the older part of the Chandalar fan. The valley train and Marten Creek fan have been trenched by the modern stream. Therefore, the older part of the Chandalar alluvial fan may be equivalent in age to the valley train and outwash from the oldest lateral moraine.

At Venetie, deposits of the older part of the Chandalar alluvial fan are exposed in banks that are 33 feet high. The alluvium is stained and selectively cemented by iron oxide. Residents of the village collected part of a jawbone, with teeth, of Equus lambei Hay[1/] from the base of the riverbank. The age of this horse is given as early to middle Pleistocene, an age that is consistent with the deep oxidation of the sediments, and with the interpretation that the older part of the Chandalar fan was deposited contemporaneously with outwash from the oldest lateral moraine on the East Fork. Further field work, with good topographic control, would be necessary to trace the terrace upstream from Venetie through the canyon to the oldest end moraine on the Chandalar River, 6 miles west of the confluence of the East Fork.

The older part of the Chandalar alluvial fan, therefore, is regarded as of early to middle Pleistocene age, and the younger part of the fan, west of the river, is probably equivalent to the middle to late Pleistocene moraines. The older parts of the fans of the Christian and Sheenjek Rivers may be of equivalent age to that of the Chandalar. The younger parts of the fans of all three rivers seem comparable in physiographic form and degree of oxidation, and may be of the same age.

The small streams crossing the marginal escarpment have deposited small alluvial fans at the edge of the Yukon Flats. Most of the fans consist of silt and organic silt that mantle the deposits of the alluvial fans and related terraces of the larger rivers. Their surficial sediments are probably of Recent age.

Flood-plain and low-terrace alluvium bordering the modern stream channels is of Recent age.

[1/] Identified by Jean Hough, U. S. Geological Survey, who prefers that E. lambei be considered a subspecies of E. caballus.

PERMAFROST

Permafrost is widespread, but is areally discontinuous and of variable thickness. Unfrozen zones occur beneath rivers, large lakes, and lakes that occupy recently abandoned stream channels, and permafrost is probably absent in local well-drained sites on terraces and alluvial fans. The only measurement of its thickness was made in the Fort Yukon well, located on a dune. The driller logged permafrost to a depth of 320 feet, but noted that ice lenses occurred between 320 and 390 feet. The sample collected from cuttings at a depth of 393 feet was reportedly frozen.

Ground ice within permafrost is common in organic silt of muskegs in the southeastern and western parts of the Yukon Flats and on poorly drained terraces along rivers in the marginal upland. Ice masses occur in alluvial-silt fans along the edge of the Yukon Flats and in loess and creek-valley silt of the marginal upland. Widely spaced ice wedges, as much as 3 feet in width, may occur where surficial silt of the flood plain, alluvial fan, and terrace alluvium of the Yukon Flats exceeds 8 feet in thickness.

After inundation by the reservoir, the permafrost in the flooded area will thaw. Although some differential settling of the ground may be expected in local areas containing ground ice, the effect on the reservoir would be insignificant. Of greater importance is the combination of ice-rich permafrost and frost-susceptible materials in the loess and creek-valley deposits of the marginal upland. These thick, frozen deposits would form the surficial materials of a broad belt of land bordering the west, south, and east sides of the reservoir and would offer difficulties in constructing roads, airfields, and other structures. In addition, local mudflows in these materials may occur as permafrost thaws, and landslides may occur where slopes are oversteepened by wave action along the margin of the reservoir.

SUMMARY AND CONCLUSIONS

The Yukon Flats Cenozoic Basin is divided into the Yukon Flats and the marginal upland, which are separated by the marginal escarpment. The escarpment and the bluffs bordering stream valleys through the upland would form the shoreline of the reservoir for the proposed Rampart Dam.

The Yukon Flats, which would be flooded by the reservoir, are formed of alluvial-fan and related terrace deposits, flood-plain and low-terrace deposits, and local deposits of alluvial-fan silt and dune sand, all of Quaternary age. At Fort Yukon, these sediments are underlain by more than 292 feet of silt and silty sand of late Tertiary or early Quaternary age. The thickness of the silt and silty sand suggests that it is widely distributed beneath the Yukon Flats. The presence or absence of consolidated Tertiary (Oligocene?) rocks and the depth to pre-Cenozoic basement rocks are yet to be determined by drilling. Permafrost is widespread, and is at least 320 feet deep in the Fort Yukon test well, the only subsurface record. Permafrost is probably absent beneath riverbeds, large lakes, lakes occupying former river channels, and certain well drained localities on terraces and alluvial fans.

The marginal upland would lie, for the most part, above the level of the reservoir, and would be the locus of most construction work along the margins of the reservoir. The upland is underlain by pre-Cenozoic basement rocks which are exposed locally in the marginal escarpment and in bluffs bordering the major valleys. These rocks are covered between Dall and Hodzana Rivers by an unknown thickness of consolidated, stratified rocks that may be similar to the coal-bearing consolidated rocks of Tertiary (Oligocene?) age reported in the Dall and Hodzana Valleys. Basalt of Tertiary age crops out near the confluence of East Fork and the

Chandalar River. Elsewhere, the pre-Cenozoic rocks are covered by unconsolidated high-level alluvium of late Tertiary or early Quaternary age. North of the Yukon and Porcupine Rivers the high-level alluvium is at the surface, but in the upland west, south, and east of the Yukon Flats it is mantled by loess of Quaternary age. Eolian sand of Quaternary age occurs locally in the marginal upland north and west of the Yukon Flats. The marginal upland is underlain by permafrost at most localities, but its thickness is unknown. Ground ice masses in the loess and creek-valley deposits of the upland will affect construction and land utilization over a broad area bordering the south, west, and east sides of the reservoir.

Additional geologic studies in the reservoir area and particularly in the adjoining sections of the marginal upland are necessary to provide an adequate appraisal of foundation conditions, potential construction materials, shoreline changes, rate of sedimentation in the reservoir, effect of flooding on permafrost beneath the reservoir, effect of climatic changes caused by proximity of the reservoir on permafrost in the marginal upland, water supply, and mineral resources. To solve existing scientific problems requires additional studies, such as geologic and paleontological studies of the high-level alluvium; paleontological and stratigraphic studies of the coal-bearing Tertiary consolidated rocks; geophysical investigations and drilling to determine the configuration and depth of the pre-Cenozoic basement rocks and stratigraphy of the Cenozoic rocks beneath the Yukon Flats; investigation of the glacial history of the southern Brooks Range to provide a more precisely dated sequence to which to tie the alluvial deposits of the Yukon Flats.

REFERENCES CITED

Brosgé, W. P., and Reiser, H. N., 1962, Preliminary geologic map of the Christian quadrangle, Alaska: U. S. Geol. Survey open-file map, 2 sheets.

Detterman, R. L., Bowsher, A. L., and Dutre, J. T., Jr., 1958, Glaciation on the Arctic slope of the Brooks Range, northern Alaska: Arctic, v. 11, no. 1, p. 43-61.

Gronewald, G. J., 1960, Engineering problems in connection with Rampart Canyon hydro-electric project: Alaskan Sci. Conf. Proc., 11th, Juneau 1960, p. 70-71.

Karlstrom, T. N. V., 1957, Tentative correlation of Alaskan glacial sequences, 1956: Science, v. 125, no. 3237, p. 73-74.

MacNeil, F. S., and others, 1961, Correlation of Tertiary formations of Alaska: Am. Assoc. Petrol. Geologists Bull., v. 45, no. 11, p. 1801-1809.

Mendenhall, W. C., 1902, Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska by way of Dall, Kanuti, Allen and Kowak Rivers: U. S. Geol. Survey P of. Paper 10, p. 41-42.

Mertie, J. B., Jr., 1929, The Chandalar-Sheenjek district, Alaska: U. S. Geol. Survey Bull. 810-B, p. 137.

U. S. Dept. Commerce, 1960, United States census of population, 1960: U. S. Dept. Commerce, Bureau of the Census, Final Rept. PC(1)-3A, table 8.

U. S. Geological Survey, 1963, Surface water records of Alaska, 1961: U. S. Geol. Survey Basic Data Release, 131 p.

Williams, J. R., 1962, Geologic reconnaissance of the Yukon Flats district, Alaska: U. S. Geol. Survey Bull. 1111-H, p. 289-331.